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am the translator of the documents attached and I state that the following is a true translation to the best of my knowledge and belief of Japanese Patent Application No. 11-251528.

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[Title of the Invention] Raman optical amplifier

[Scope of claims]

[Claim 1]

A Raman optical amplifier that guides signal light and pump light emitted from a semiconductor laser element to an optical fiber to subject the signal light to Raman optical amplification in the optical fiber, characterized in that pump light is obtained by depolarizing the oscillation light emitted from the semiconductor laser element through a depolarizer.

[Claim 2]

A Raman optical amplifier according to claim 1, characterized in that the depolarizer is structured such that a birefringent optical fiber, which is connected such that a principal axis of a plane of polarization thereof coincides with a plane of polarization of the oscillation light from the semiconductor laser element, is connected with a different depolarizing birefringent optical fiber such that principal axes of planes of polarization of both the birefringent optical fibers differ from each other.

[Claim 3]

A Raman optical amplifier according to claim 2, characterized in that the birefringent optical fiber and the depolarizing birefringent optical fiber are structured to be connected with each other such that the principal axes of the planes of polarization

thereof are inclined at an angle of 45°.

[Claim 4]

A Raman optical amplifier according to claim 1, characterized in that the depolarizer is structured such that the semiconductor laser element is connected to a depolarizing birefringent optical fiber such that a plane of polarization of the oscillation light of the semiconductor laser element and an optical principal axis of the depolarizing birefringent optical fiber relatively form an angle.

[Claim 5]

A Raman optical amplifier according to claim 4, characterized in that the semiconductor laser element is connected with a birefringent optical fiber such that the plane of polarization of the oscillation light of the semiconductor laser element and the optical principal axis of the depolarizing birefringent optical fiber form an angle of 45°.

[Claim 6]

A Raman optical amplifier according to claim 1, characterized in that the depolarizer is structured by inserting a polarization controller between a birefringent optical fiber connected to the semiconductor laser element and a different depolarizing birefringent optical fiber.

[Claim 7]

A Raman optical amplifier according to claim 1, characterized

in that the depolarizer is structured such that: the oscillation light emitted from the semiconductor laser element is distributed into two with equal optical intensities by means of an optical distributor; the distributed lights are guided to different depolarizing birefringent optical fibers to produce a phase difference between the distributed lights; and then, the distributed lights are synthesized again.

[Claim 8]

A Raman optical amplifier according to claim 7, characterized in that the respective distributed lights are guided to a fast axis of one of the depolarizing birefringent optical fibers and a slow axis of the other depolarizing birefringent optical fiber.

[Claim 9]

A Raman optical amplifier according to claim 7 or 8, characterized in that a polarization controller is inserted between the semiconductor laser element and the optical distributor.

[Claim 10]

A Raman optical amplifier according to any one of claims 2 to 9, characterized in that a degree of depolarization is regulated or adjusted by changing a length of the depolarizing birefringent optical fiber.

[Claim 11]

A Raman optical amplifier according to any one of claims 1 to 10, characterized in that the birefringent optical fiber or the

depolarizing birefringent optical fiber is provided with a fiber grating.

[Detailed Description of the Invention]

[0001]

[Technical Field to which the Invention belongs]

The present invention relates to a Raman optical amplifier that amplifies signal light utilizing an induced Raman scattering phenomenon.

[0002]

[Prior Art]

Raman gain, which is subjected to Raman amplification in an optical fiber as an amplification medium, strongly depends on a mutual relationship in polarization state between pump light and signal light. For example, in the case where polarized waves of the pump light consist of linearly polarized waves (Laser light emitted from a semiconductor laser element (LD) generally has a linearly polarized state.), Raman amplification gain increases when the signal light consists of linearly polarized waves parallel to the polarized waves of the pump light while Raman gain decreases when the signal light consist of linearly polarized waves perpendicular to the polarized waves of the pump light.

[0003]

When the polarization state of the pump light or signal light fluctuates over time in the optical fiber as the amplification medium,

the gain also fluctuates over time. The fluctuation in gain is not preferable from the viewpoint of information transmission.

[0004]

Therefore, in a conventional case: at least two LDs per wavelength and a polarization synthesizer are used for a pumping light source; polarization synthesis is performed such that the respective polarized waves are perpendicular to each other; and the resultant is inputted to the optical fiber as the amplification medium, thereby solving polarization dependence of the Raman amplification gain.

[0005]

[Problems to be solved by the Invention]

Conventionally, at least the two LDs for pumping have been required as described above for solving the polarization dependence of the pump light. Thus, there has been limitation placed on cost reduction and reduction in size of a Raman amplifier. In order to solve the problems, it is effective to use one LD for pumping. However, the use of one pumping LD causes the temporal fluctuation in Raman amplification gain due to the temporal fluctuation in polarized state of the pump light or signal light.

[0006]

The fluctuation in Raman amplification gain, which depends on polarization, is not preferable for stabilization of information communication. Thus, the polarization dependence of the Raman

amplification gain needs to be solved. Reduction of the number of pumping LDs can realize cost reduction, reduction in size of a device, which results from reduction of the number of parts, and simplification of a manufacturing process.

[0007]

[Means for solving the Problems]

The present invention has been made in view of the above, and therefore has an object to provide a Raman optical amplifier, in which gain is stabilized by solving polarization dependence of the gain with the use of a depolarized pumping LD light source as a pump light source of the Raman optical amplifier. Also, the present invention has another object to provide a simplified device through reduction of the number of parts thereof.

[0008]

The invention of claim 1 relates to a Raman optical amplifier that guides signal light and pump light emitted from a semiconductor laser element (plural LDs having different wavelengths in case of multiplexing waves (one LD for each wave)) to an optical fiber to subject the signal light to Raman optical amplification in the optical fiber, which is characterized in that pump light is obtained by depolarizing the oscillation light emitted from the semiconductor laser element through a depolarizer.

[0009]

The invention of claim 2 relates to the Raman optical amplifier

according to claim 1, characterized in that the depolarizer is structured such that a birefringent optical fiber, which is connected such that an optical principal axis of a plane of polarization thereof coincides with a plane of polarization of the oscillation light from the semiconductor laser element, is connected with a different depolarizing birefringent optical fiber such that optical principal axes of planes of polarization of both the birefringent optical fibers have relative angle difference.

[0010]

The invention of claim 3 relates to the Raman optical amplifier according to claim 2, characterized in that the birefringent optical fiber and the depolarizing birefringent optical fiber are structured to be connected with each other such that both the principal axes of the planes of polarization are inclined at an angle of 45°.

[0011]

The invention of claim 4 relates to the Raman optical amplifier according to claim 1, characterized in that the depolarizer is structured such that the semiconductor laser element is connected to a depolarizing birefringent optical fiber such that a plane of polarization of the oscillation light of the semiconductor laser element and an optical principal axis of the depolarizing birefringent optical fiber relatively form an angle.

[0012]

The invention of claim 5 relates to the Raman optical amplifier

according to claim 4, characterized in that the semiconductor laser element is connected with a birefringent optical fiber such that the plane of polarization of the oscillation light of the semiconductor laser element and the optical principal axis of the depolarizing birefringent optical fiber relatively form an angle of 45°.

[0013]

The invention of claim 6 relates to the Raman optical amplifier according to claim 1, characterized in that the depolarizer is constituted by inserting a polarization controller between a birefringent optical fiber connected with the semiconductor laser element and a different depolarizing birefringent optical fiber. The polarization controller fulfills a function of adjusting a polarization state of light inputted to the depolarizing birefringent optical fiber to the optimum state for depolarization.

[0014]

The invention of claim 7 relates to the Raman optical amplifier according to claim 1, characterized in that: the oscillation light emitted from the semiconductor laser element is distributed into two with equal optical intensities by means of an optical distributor; the distributed lights are guided to different depolarizing birefringent optical fibers to produce a phase difference between the distributed lights; and then, the distributed lights are synthesized again.

[0015]

The invention of claim 8 relates to the Raman optical amplifier according to claim 7, characterized in that one of the distributed lights is guided to a fast axis of one of the depolarizing birefringent optical fibers, and the other of the distributed lights is guided to a slow axis of the other depolarizing birefringent optical fiber.

[0016]

The invention of claim 9 relates to the Raman optical amplifier according to claim 7 or 8, characterized in that a polarization controller is inserted between the semiconductor laser element and the optical distributor. The polarization controller fulfills a function of adjusting a polarization state of light inputted to the depolarizing birefringent optical fiber to the optimum state for depolarization.

[0017]

The invention of claim 10 relates to the Raman optical amplifier according to any one of claims 2 to 9, characterized in that a degree of depolarization is regulated by changing a length of one or two depolarizing birefringent optical fibers.

[0018]

The invention of claim 11 relates to the Raman optical amplifier according to any one of claims 1 to 10, characterized in that the birefringent optical fiber or the depolarizing birefringent optical fiber is provided with a fiber grating.

[0019]

The core of the birefringent optical fiber has different refractive indexes in a longitudinal direction and a transverse direction relative to a section of the optical fiber. Thus, when electromagnetic waves propagate in the birefringent optical fiber, the electromagnetic wave whose polarization is parallel to the longitudinal direction differs in velocity from the electromagnetic wave whose polarization is parallel to the transverse direction. In general, an axis with the fastest propagation velocity is referred to as a fast axis, and an axis with the slowest propagation velocity, which is perpendicular to the fast axis, is referred to as a slow axis.

[0020]

A propagation velocity difference in the above propagation modes is utilized for depolarization. The electromagnetic waves (LD light) are inputted to the birefringent optical fiber such that polarization of the electromagnetic waves forms an angle of 45° relative to the fast axis. The birefringent optical fiber, which is conventionally connected with an LD, is connected with a connection terminal structured through combination of lenses so as to attain the maximum extinction ratio.

[0021]

In this case, polarization of LD light is parallel to the optical principal axis (fast axis or slow axis) of the birefringent optical

fiber and propagates in the birefringent optical fiber while its polarization state is preserved. In such a case, as in claim 2 or 3, the birefringent optical fiber, which is connected to the LD, is connected with the birefringent optical fiber for depolarization such that the optical principal axes of those birefringent optical fibers have a relative angle difference (desirably through rotation of 45°). As a result, electromagnetic wave modes can be pumped in which electromagnetic waves propagate parallel to the fast axis and slow axis with the same intensities.

[0022]

Further, as in claims 4 and 5, the birefringent optical laser is connected to the semiconductor laser element so as to form an angle (desirably through rotation of 45°) relative to the plane of polarization of the laser light emitted from the semiconductor laser element. As a result, both the electromagnetic wave modes are also pumped, thereby being capable of depolarizing the pump light.

[0023]

Further, as in claim 6, the polarization controller is inserted between the birefringent optical fiber, which is connected to the semiconductor laser element, and the different depolarizing birefringent optical fiber. As a result, both the propagation modes can be pumped with the same intensities, thereby being capable of depolarizing the laser light.

[0024]

Further, as in claims 7 to 9, the oscillation light emitted from the semiconductor laser element is distributed into two with the same intensities, the distributed lights are guided to the different depolarizing birefringent optical fibers to produce the phase difference between the distributed lights, and then, the lights are synthesized again. As a result, the pump light can be depolarized.

[0025]

Further, as in claim 10, the degree of depolarization can be adjusted by changing the length of the depolarizing birefringent optical fiber.

[0026]

Further, the following technique has been adopted in which an optical fiber connected to an output terminal of an LD is provided with a fiber grating portion that reflects oscillation light of the LD to structure an external resonator of the LD, which is intended to narrow a band of the oscillation light. The technique can be also applied to the present invention (Claim 11).

[0027]

As to means for producing the phase difference between the distributed lights, one of the distributed lights is inputted such that polarization thereof is parallel to the fast axis of one of the depolarizing birefringent optical fibers while the other distributed light is inputted such that polarization thereof is

parallel to the slow axis of the other depolarizing birefringent optical fiber. At this point, each of the depolarizing birefringent optical fibers is set to have a length enough to sufficiently depolarize the LD light that uses the optical path difference resulting from the difference in refractive index between the fast axis and the slow axis. In addition, the depolarizing birefringent optical fibers are provided with the same lengths.

[0028]

Further, as to another means for producing the phase difference between the distributed lights, the two depolarizing birefringent optical fibers are provided to have different lengths. The length of each of the two depolarizing birefringent optical fibers is set such that the total optical path difference, which is calculated based on the difference in refractive index between the fast axis and the slow axis and the difference in length between the two depolarizing birefringent optical fibers, enables sufficient depolarization of the semiconductor laser light.

[0029]

Further, as to still another means for producing the phase difference between the distributed lights, the difference in length of the two depolarizing birefringent optical fibers is set to attain sufficient depolarization of the semiconductor laser light without special limitation on a polarization direction of the distributed light, thereby enabling depolarization.

[0030]

In the birefringent optical fiber, the electromagnetic waves of both the modes are independent and differ in propagation velocity from each other. Thus, the electromagnetic waves, which propagate in both the modes in the birefringent optical fiber, involve the passing time difference corresponding to the length of the birefringent optical fiber. The time difference is equivalent to the optical path difference. In the case where the optical path difference is longer than a coherent length of the electromagnetic wave of the used light source, phase correlation between the electromagnetic wave propagating parallel to the fast axis and the electromagnetic wave propagating parallel to the slow axis is weakened at an exit of the birefringent optical fiber (Weakening of the phase correlation means lowering of coherence.). Therefore, the coherence is low when the electromagnetic waves of both the modes are overlapped with each other at the exit of the birefringent optical fiber. Accordingly, there is obtained an effect that the degree of polarization reduces compared with the degree at the time of input.

[0031]

The degree of polarization is represented by using DOP (degree of polarization) obtained by expressing, in percentage, the ratio between the sum of an intensity of a polarization component and an intensity of a depolarization component and the intensity of

the polarization component. The DOP value depends on the coherent length of the electromagnetic wave and the optical path difference of the electromagnetic waves that propagate through the fast axis and slow axis of the birefringent optical fiber. The optical path difference depends on the length of the birefringent optical fiber. Thus, the DOP value depends on the length of the birefringent optical fiber. As the birefringent optical fiber becomes longer, the polarization component decreases gradually.

[0032]

Fig. 12 shows a relationship between the DOP value and the length of the birefringent optical fiber. The relationship is obtained from the results of the measurement of the degree of polarization in which a polarization measuring device is connected to a tip end of the depolarizing birefringent optical fiber at an input terminal of the optical coupler 7 in the embodiment of Fig. 1, which will be described later. It is found from the results that the degree of polarization is adjusted by adjusting the length of the birefringent optical fiber or depolarizing birefringent optical fiber, thereby enabling control of the DOP value.

[0033]

[Embodiment Mode of the Invention]

Figs. 1 to 11 show embodiments of the present invention in which oscillation light in a polarization state, which is emitted from a semiconductor laser element, is depolarized by a depolarizer.

[0034]

In Figs. 1 to 3, reference numeral 1 denotes a semiconductor laser element; 2, a birefringent optical fiber; 3, a connector for connecting the semiconductor laser element 1 with the birefringent optical fiber 2; 4, a depolarizing birefringent optical fiber; 5, a connection portion between the birefringent optical fiber 2 and the depolarizing birefringent optical fiber 4; 6, signal light; 7, an optical coupler that combines the signal light 6 with pump light; 8, a quartz optical fiber; and 9, a fiber grating.

[0035]

The semiconductor laser element 1 is selected which emits oscillation light having a wavelength shorter by 50 to 200 nm (desirably, about 100 nm) than that of the signal light 6.

As shown in Figs. 2 and 3, the birefringent optical fiber 2 and the depolarizing birefringent optical fiber (PANDA fiber) 4 each are composed of a core with a high refractive index at a central portion thereof and a cladding with a low refractive index at a peripheral portion thereof. The core is placed in the cladding to arrange a stress imparting layer, which generates different birefringent indexes (fast axis or slow axis) in a horizontal direction and vertical direction to a direction perpendicular to the core.

[0036]

Further, the birefringent optical fiber 2 is provided with

a light reflecting layer, which substantially coincides with the oscillation light from the semiconductor laser element 1 and which is formed by the fiber grating 9. As a result, stabilization of an oscillation wavelength and a narrower band thereof are attempted.

[0037]

The semiconductor laser element 1 and the birefringent optical fiber 2 are connected to each other through the connector 3 such that a plane of polarization of the oscillation light of the semiconductor laser element 1 coincides with an optical principal axis (fast axis or slow axis) of the birefringent optical fiber 2 (such that an extinction ratio is at the maximum). Thus, the plane of polarization of the oscillation light emitted from the semiconductor laser element 1 is kept to be guided to the birefringent optical fiber.

[0038]

The birefringent optical fiber 2 and the depolarizing birefringent optical fiber 4 are connected with each other such that there is a relative difference in angle between optical principal axes of both the birefringent optical fibers, as shown in Fig. 2, whereby the depolarizer is structured. Therefore, specific polarized waves, which are guided to the birefringent optical fiber 2, are subjected to division at a certain ratio to the fast and slow axes of the depolarizing birefringent optical fiber 4, which can realize depolarization.

[0039]

The optical principal axes of both the birefringent optical fibers are connected through rotation by 45° as shown in Fig. 3. Thus, the polarized waves are subjected to division to the fast and slow axes at a ratio of 1:1, which can completely achieve depolarization.

[0040]

Further, although not shown in the figure, as the depolarizing birefringent optical fiber 4 shown in Fig. 1, a LYOT type depolarizer having two birefringent optical fibers, with lengths at a ratio of 1:2, may be adopted which are fused together such that optical principal axes thereof are inclined at an angle of 45°.

[0041]

When a connection angle of the birefringent optical fibers is changed by using the birefringent optical fiber 2 and the depolarizing birefringent optical fiber 3 with equal lengths, a DOP value becomes large compared with the case of the connection angle of 45°. That is, the DOP value can be controlled by changing the connection angle of the birefringent optical fibers.

[0042]

Conventionally, in order to solve polarization dependence of Raman amplification gain, at least two LDs and a polarization synthesizer are used to perform polarization synthesis such that polarized waves of lights from the LDs are perpendicular to each

other, and the resultant is inputted to an optical fiber as an amplification medium.

[0043]

In the present invention, the oscillation light emitted from the semiconductor laser light is depolarized by the depolarizer to be inputted to the optical fiber 8 as the Raman amplification medium, thereby solving the polarization dependence of the Raman amplification gain. As to the polarization dependence of Raman gain, the Raman amplification gain is measured while the polarization state of the signal light for amplification is changed. Then, the difference between the maximum value and the minimum value through the measurement is taken as a PDG (polarization dependent gain) value, and the value is used for evaluation of the polarization dependence.

[0044]

Fig. 13 shows results of the measurement of the PDG value through changing the DOP value with the use of a Raman amplification method of the present invention. Fig. 13 indicates that the PDG value decreases with the decrease of the DOP value. That is, Fig. 13 shows that the polarization dependence of gain is solved through Raman amplification with the use of a depolarized pumping light source. Further, the PDG value can be controlled by changing the DOP value.

[0045]

Figs. 4 and 5 show other embodiments of the present invention.

In the figures, reference numerals 1, 3, 4, and 9 respectively denote the semiconductor laser element, connector, depolarizing birefringent optical fiber, and fiber grating as in Figs. 1 to 3.

[0046]

In the embodiments, the semiconductor laser element 1 is connected to the depolarizing birefringent optical fiber 4 through the connector 3.

[0047]

In the embodiment shown in Fig. 4, the semiconductor laser element 1 is connected to the depolarizing birefringent optical fiber 4 such that the plane of polarization of the oscillation light of the semiconductor laser element 1 and the optical principal axis of the depolarizing birefringent optical fiber 4 relatively make an angle. In the embodiment shown in Fig. 5, the plane of polarization of the oscillation light of the semiconductor laser element 1 and the optical principal axis of the depolarizing birefringent optical fiber 4 are connected to each other to be inclined at an angle of 45°.

[0048]

The depolarizing birefringent optical fiber 4 is provided with the fiber grating 9, which constitutes an external resonator of the semiconductor laser element 1.

[0049]

The above embodiments also have the same effects as those of

the embodiments shown in Figs. 1 to 3.

[0050]

Fig. 6 shows still another embodiment of the present invention. In the figure, reference numerals 1, 2, 3, 4, 6, 7, and 8 respectively denote the semiconductor laser element, birefringent optical fiber, connector for connecting the semiconductor laser element1 to the birefringent optical fiber 2, depolarizing birefringent optical fiber, optical signal, optical coupler, and quartz optical fiber, as in Fig. 1. In the figure, reference numeral 10 denotes a polarization controller, which is arranged to be inserted at the connection portion 5 between the birefringent optical fiber 2 and the depolarizing birefringent optical fiber 4. The polarization controller 10 is inserted between the semiconductor laser element 1 and the depolarizing birefringent optical fiber 4, whereby the oscillation light emitted from the semiconductor laser element 1 can be freely subjected to polarization control. Therefore, the semiconductor laser element and the birefringent optical fiber as well as the birefringent optical fiber and the depolarizing birefringent optical fiber each do not need to be connected to each other with a specific connection angle, as shown in Figs. 2 to 5.

[0051]

Further, although not shown in the figure, as the depolarizing birefringent optical fiber 4 shown in Fig. 6, a LYOT type depolarizer having birefringent optical fibers, with former and latter lengths

at a ratio of 1:2, may be adopted which are fused together such that optical principal axes thereof are inclined at an angle of 45°.

[0052]

Figs. 7 to 10 show other embodiments of the present invention. In the figures, reference numerals 1, 3, 4, and 9 respectively denote the semiconductor laser element, connector, depolarizing birefringent optical fiber, and fiber grating, as in Figs. 1 to 3. In the figures, reference numerals 1, 2, 3, and 4 respectively denote the semiconductor laser element, birefringent optical fiber, connector for connecting the semiconductor laser element 1 to the birefringent optical fiber 2, and depolarizing birefringent optical fiber, as in Fig. 1. Further, in the figures, reference numeral 11 denotes an optical distributor that distributes output from the semiconductor laser element 1 at an output ratio of 1:1 (WDM coupler or polarization demultiplexer, polarization is preserved while the light passes through the optical distributor). Reference numeral 12 denotes a polarization synthesizer, and reference numeral 13 denotes an output single-mode optical fiber. Here, two fibers A and B are used for the depolarizing birefringent optical fiber 4.

[0053]

The output light from the semiconductor laser element 1 is guided to the optical distributor 11 through the birefringent optical fiber 2 to be distributed at the output ratio of 1:1. The distributed

lights are guided to the respective depolarizing birefringent optical fibers A and B, where an optical phase difference is produced between the distributed lights.

[0054]

As to an example that causes the optical phase difference, the optical distributor 11 is connected with the depolarizing birefringent optical fibers A and B such that planes of polarization of the lights, which are distributed by the optical distributor 11, become parallel to a fast axis of the depolarizing birefringent optical fiber A and a slow axis of the depolarizing birefringent optical fiber B, respectively.

[0055]

At this point, the lengths of the depolarizing birefringent optical fibers A and B are chosen such that an optical path difference between the light propagating parallel to the fast axis and the light propagating parallel to the slow axis in any of the fibers A and B is sufficient for depolarization.

[0056]

In another example that causes the optical phase difference, the lengths of the depolarizing birefringent optical fibers A and B are made different from each other. The relationship in length between the depolarizing birefringent optical fibers A and B is set such that the sum of the optical path difference resulting from the difference in refractive index of the depolarizing birefringent

optical fibers of the lights propagating through the depolarizing birefringent optical fibers A and B and the optical path difference resulting from the difference in length between the depolarizing birefringent optical fibers A and B is sufficient for depolarization.

[0057]

Accordingly, the depolarizing birefringent optical fibers A and B, which provide the phase difference between both the distributed lights, are connected with the polarization synthesizer 12. Here, the depolarizing birefringent optical fibers A and B are connected with the polarization synthesizer 12 such that synthesis is performed while the planes of polarization of the respective lights, which propagate through the depolarizing birefringent optical fibers A and B, are perpendicular to each other. As a result, the synthesized oscillation light is outputted as pump light for Raman optical amplification through the output single-mode optical fiber 13.

[0058]

At this point, in the present invention, the birefringent optical fiber 2 may be provided with the fiber grating 9 to realize stabilization of the oscillation wavelength and the reduction in wavelength of the oscillation light, as shown in Fig. 8.

[0059]

Further, as shown in Figs. 9 and 10, the polarization controller 10 may be inserted between the optical distributor 11 and the semiconductor laser element 1. This can attain free polarization

control of the oscillation light emitted from the semiconductor laser element 1. In the embodiment shown in Fig. 10, the fiber grating 9 is arranged on the input side of the polarization controller 10 for the purpose of reducing the wavelength of the oscillation light.

[0060]

Fig. 11 shows still another embodiment of the present invention. In the figure, reference numerals 1, 2, 3, 4, 6, 7, and 8 respectively denote the semiconductor laser element, birefringent optical fiber, connector for connecting the semiconductor laser element 1 with the birefringent optical fiber 2, depolarizing birefringent optical fiber, optical signal, optical coupler, and quartz optical fiber, as in Fig. 1. Reference numeral 14 denotes an optical coupler.

[0061]

This embodiment shows an example in which: plural semiconductor laser elements 1, ···, 1 with different oscillation wavelengths are arranged; oscillation lights emitted from the elements each are depolarized by the depolarizer with the structure shown in any one of Figs. 1 to 9; the respective oscillation lights are synthesized by the optical coupler 14 to be formed into pump light with the plural oscillation wavelengths; the pump light is synthesized with the optical signal; and the resultant is subjected to Raman amplification through the quartz optical fiber.

[0062]

[Effects of the Invention]

According to claim 1 of the invention, by structuring the depolarized pumping light source, it is possible to solve the polarization dependence of the gain which is caused through pumping of one semiconductor laser. Accordingly, the number of pumping semiconductor laser elements can be reduced.

[0063]

According to claims 2 to 6 of the invention, connection is established such that the optical principal axis of the depolarizing birefringent optical fiber and the plane of polarization of the semiconductor laser element or optical principal axis of the birefringent optical fiber, which is connected to the depolarizing birefringent optical fiber, relatively forms an angle. Accordingly, the degree of polarization can be appropriately adjusted.

[0064]

According to claims 7 to 9 of the invention, there is provided such an effect that: the oscillation light emitted from the semiconductor laser element is distributed into two parts; the distributed lights are guided to the different depolarizing birefringent optical fibers to produce the phase difference between the distributed lights; and thereafter, the distributed lights are synthesized again, thereby being capable of obtaining the appropriate degree of polarization.

The invention of claim 10 provides such an effect that the degree of depolarization can be adjusted by changing in length the

depolarizing birefringent optical fiber.

[0065]

The invention of claim 11 provides such an effect that the pumping light source with a narrow band can be structured by providing the birefringent optical fiber or depolarizing birefringent optical fiber with the fiber grating.

[Brief Description of the Drawings]

[Fig. 1] A structural view of a first embodiment of the present invention.

[Fig. 2] A structural view of a main part in accordance with another embodiment of the present invention.

[Fig. 3] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 4] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 5] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 6] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 7] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 8] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 9] A structural view of a main part in accordance with still

another embodiment of the present invention.

[Fig. 10] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 11] A structural view of a main part in accordance with still another embodiment of the present invention.

[Fig. 12] A graph showing characteristics of a degree of polarization to a depolarizing birefringent optical fiber in accordance with the embodiments of the present invention.

[Fig. 13] A graph showing characteristics of polarization dependence of gain to the degree of polarization in accordance with the embodiments of the present invention.

[Description of Symbols]

1 ·· semiconductor laser element

2 ·· birefringent optical fiber

3 ·· connector

4 ·· depolarizing birefringent optical fiber

5 ·· connection portion

6 ·· signal light

7 ·· optical coupler

8 ·· optical fiber

9 ·· fiber grating

10 ·· polarization controller

11 ·· optical distributor

12 ·· polarization synthesizer

13 ·· output single-mode optical fiber

14 ·· optical coupler

A ·· depolarizing birefringent optical fiber

B ·· depolarizing birefringent optical fiber

[Document Name] Abstract

[Summary]

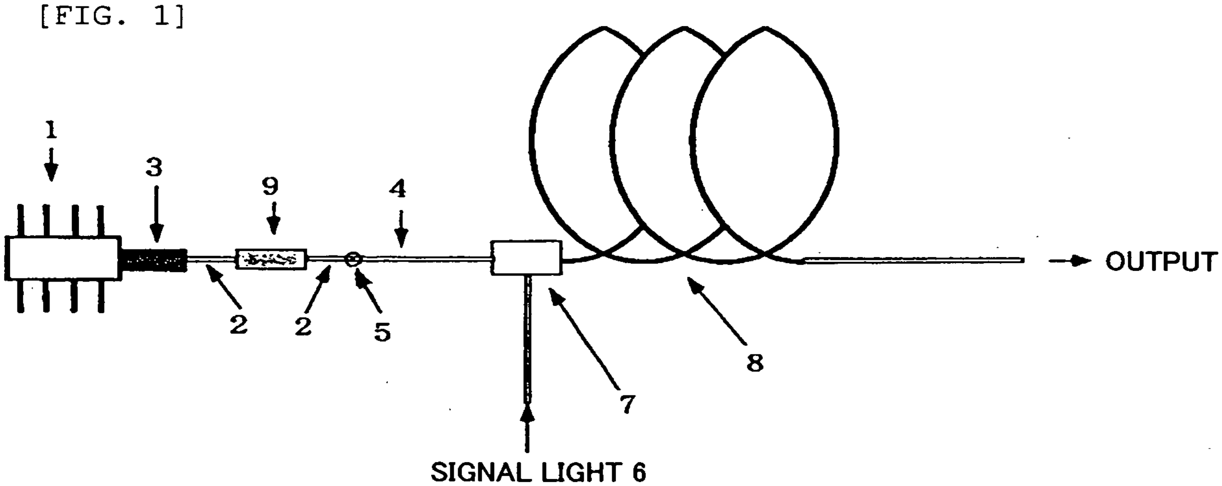
[Problem] The use of one pumping semiconductor laser element causes the temporal fluctuation in Raman amplification gain due to the temporal fluctuation in polarized state of the pump light or signal light.

[Solving Means] A Raman optical amplifier that guides signal light and pump light emitted from a semiconductor laser element to an optical fiber to subject the signal light to Raman optical amplification in the optical fiber, characterized in that pump light is obtained by depolarizing the oscillation light emitted from one semiconductor laser element through a depolarizer.

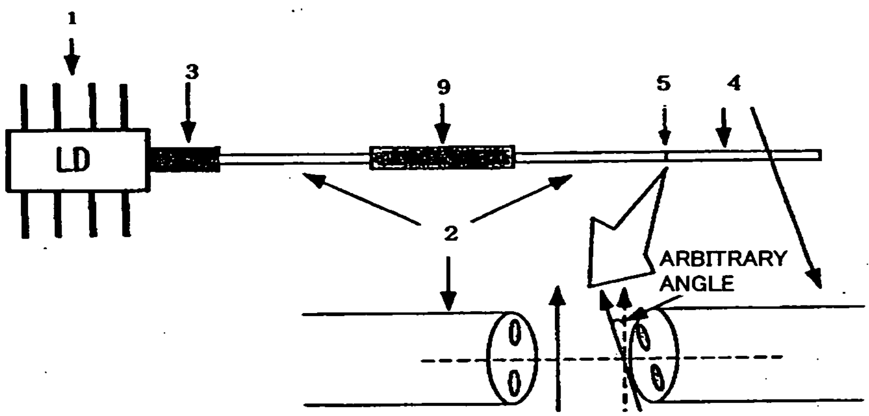
[Selected Drawing] Fig. 1

[Document Name] Drawings

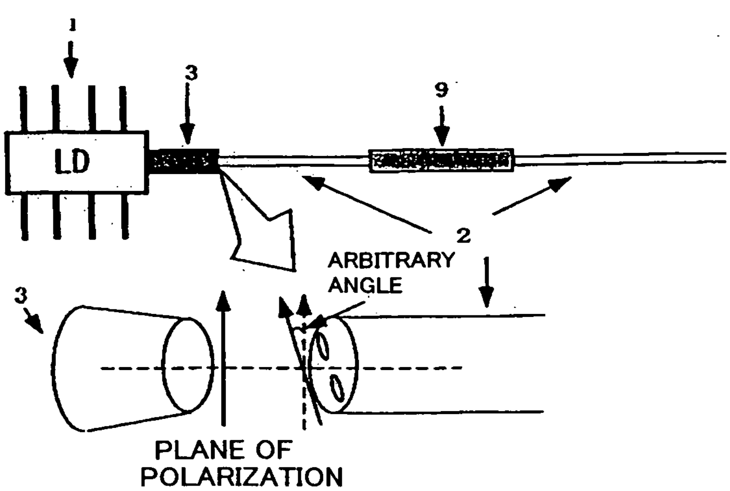
[FIG. 1]



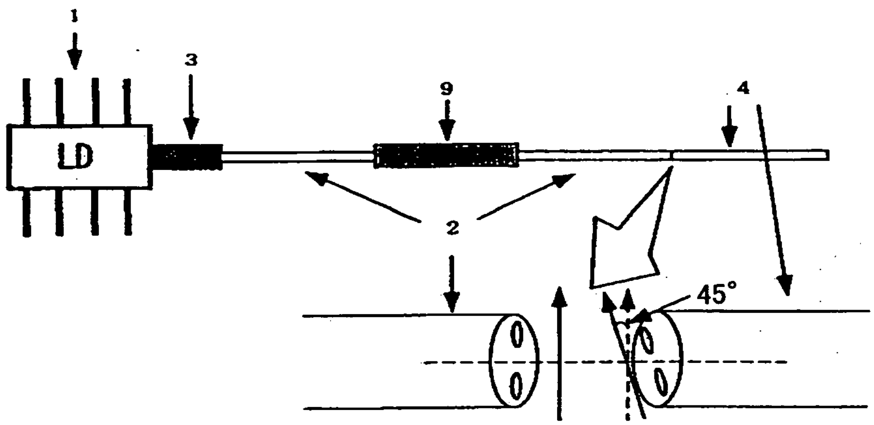
[FIG. 2]



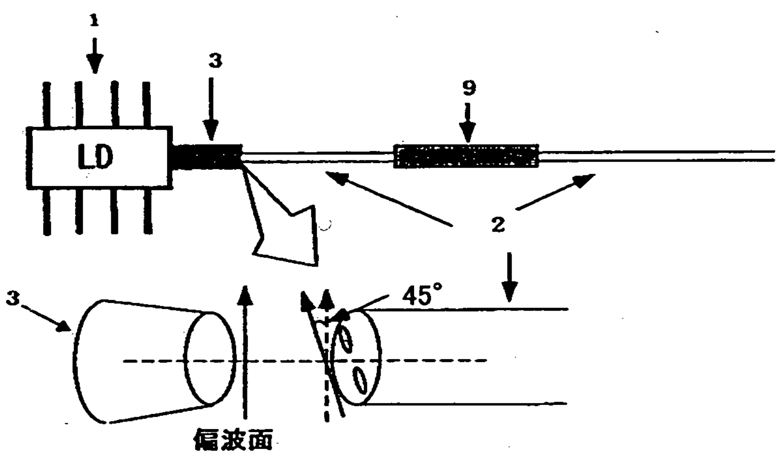
[FIG. 3]



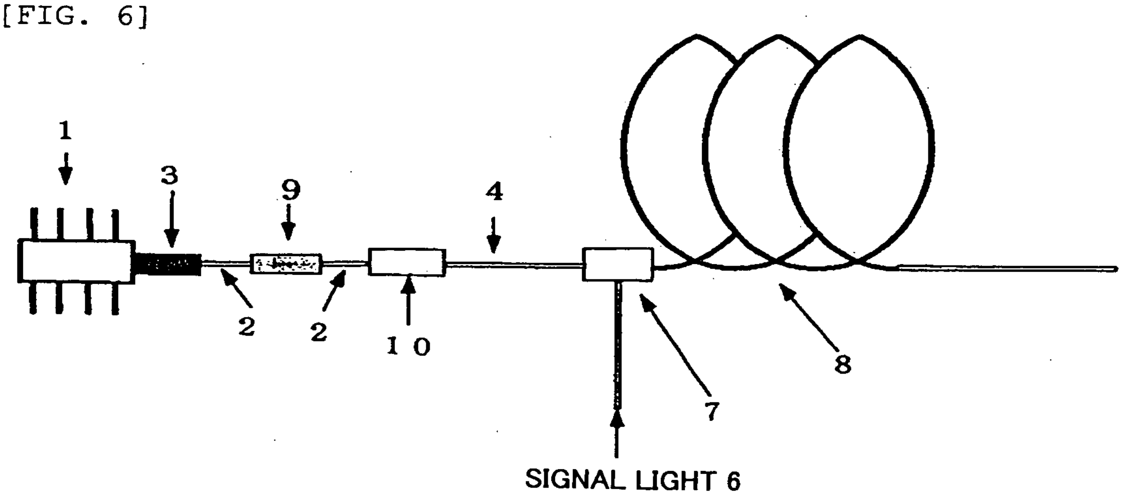
[FIG. 4]



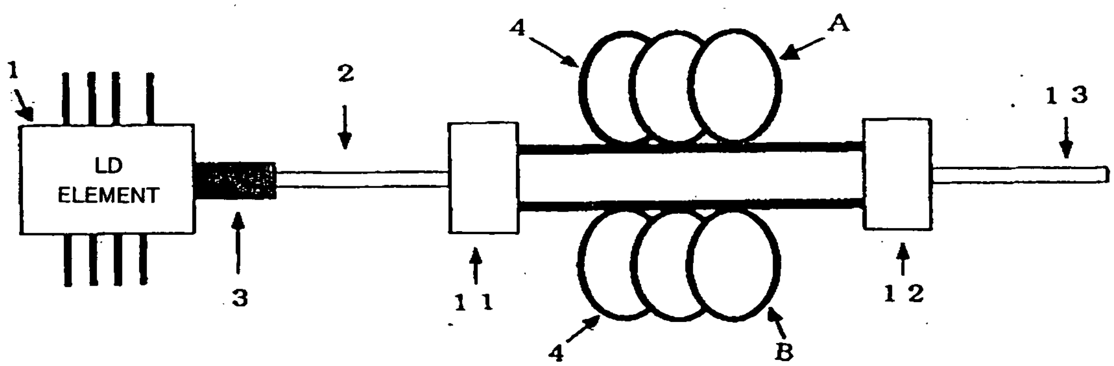
[FIG. 5]



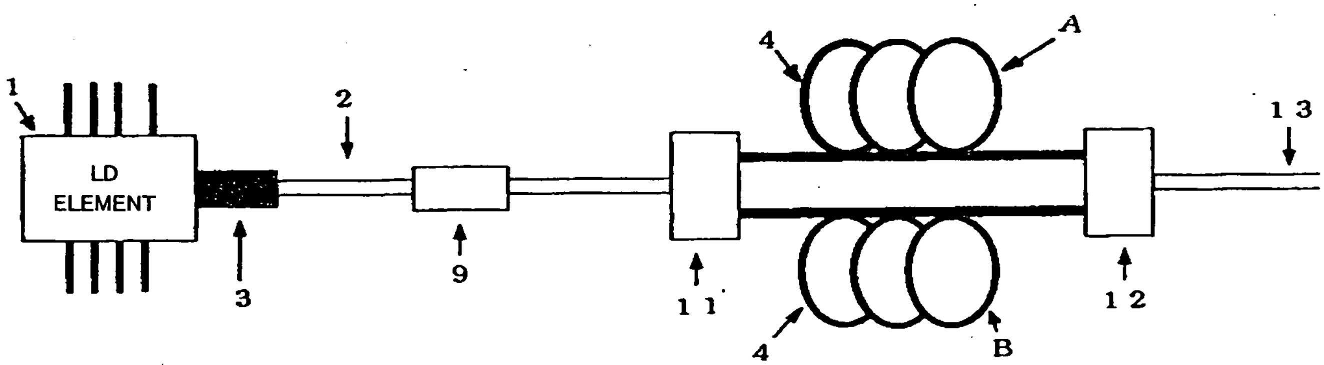
[FIG. 6]



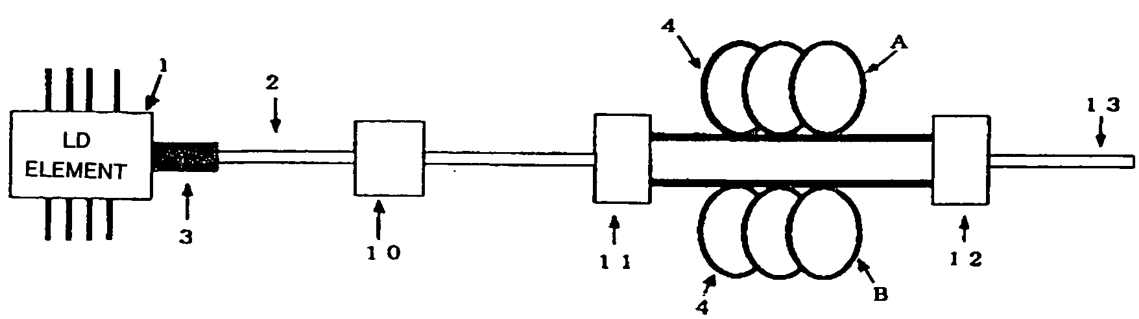
[FIG. 7]



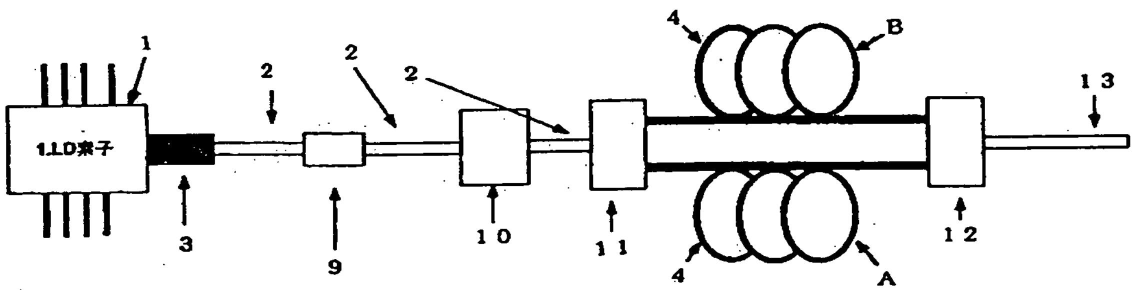
[FIG. 8]



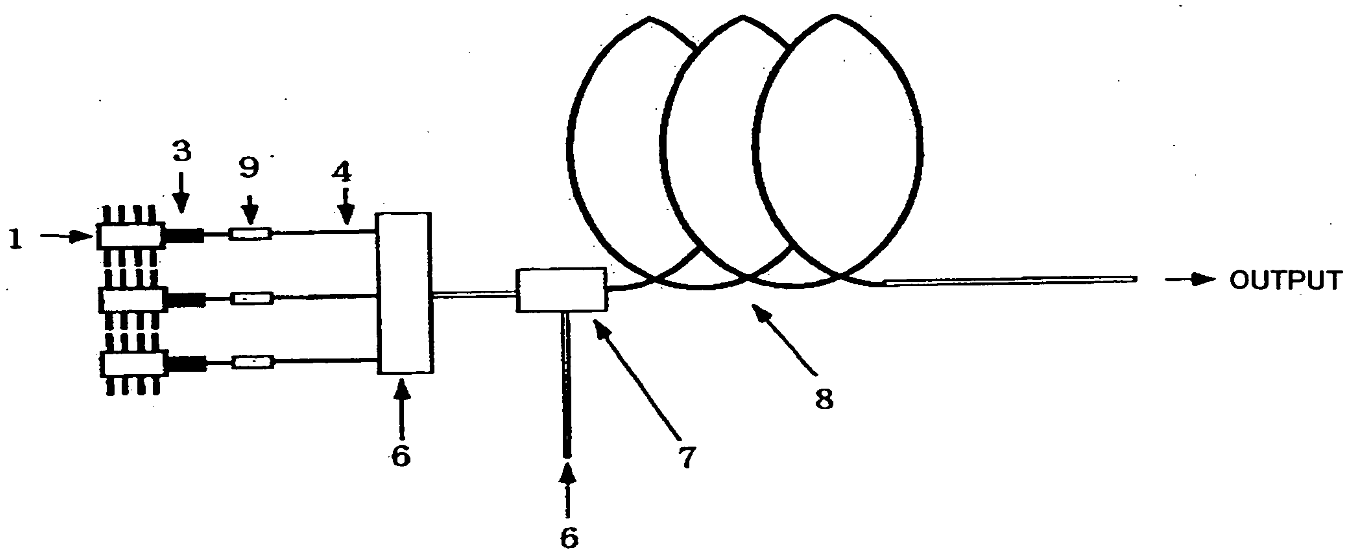
[FIG. 9]



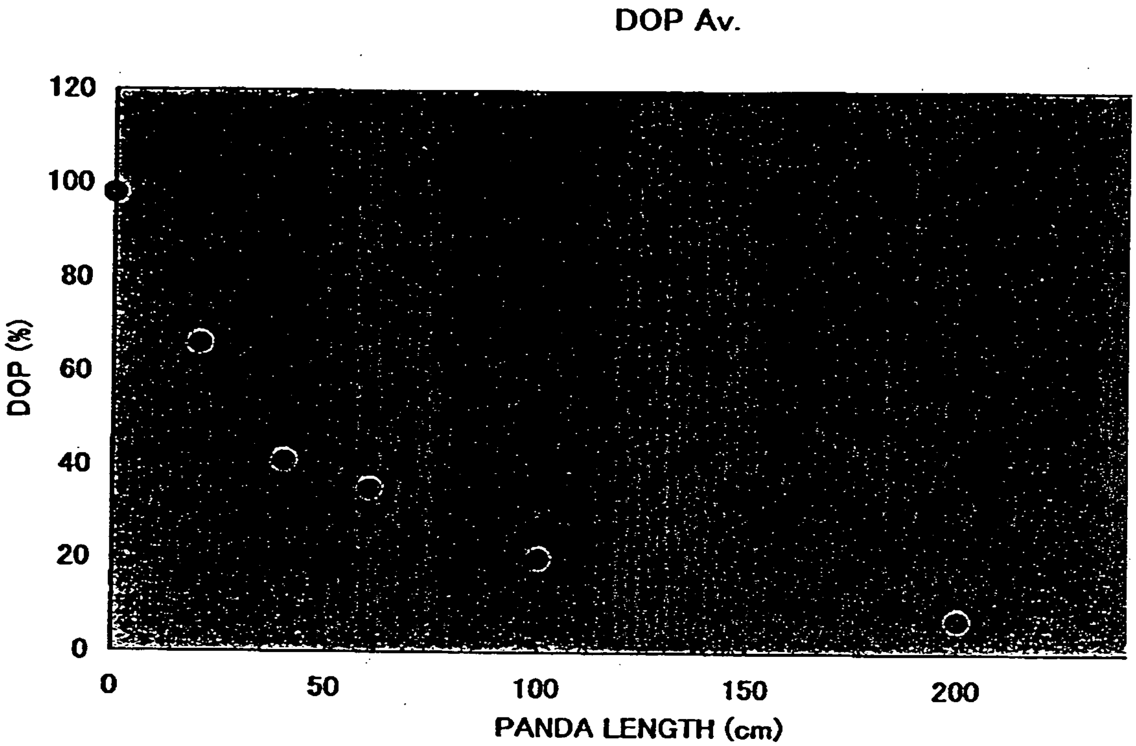
[FIG. 10]



[FIG. 11]



[FIG. 12]



[FIG. 13]